MATHEMATICAL DOWSERS AND DIGITAL DIVINERS

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According to many reports, an expert dowser is a handy person to have about if one is interested in locating such items as wells, buried treasure, and the like. All that is required is a stroll about the area, dowsing stick in hand. At the appropriate spot, the stick twitches convulsively, and digging commences. Since the successes are well-documented and advertised, and the failures ignored, by employer and employee alike, it is not altogether easy to evaluate the relative efficiency of this procedure as compared, let us say, to that used by the geologist, or one based on the use of a Ouija board. But the persistent belief in astrology, telepathy, extrasensory perception, and similar supernatural phenomena attest to the human desire to believe in magic, and, above all, in magical powers of perception. There is certainly good reason for this belief, considering the telephone, the camera, the X-ray machine, hypnosis, the electron microscope, and so on. It is not as easy to distinguish between a respectable and unrespectable belief in magic as one might suppose.

The most recent, and most powerful, Sorcerer's Apprentice is, of course, the digital computer. It is respectable when manned by a reputable scientist or

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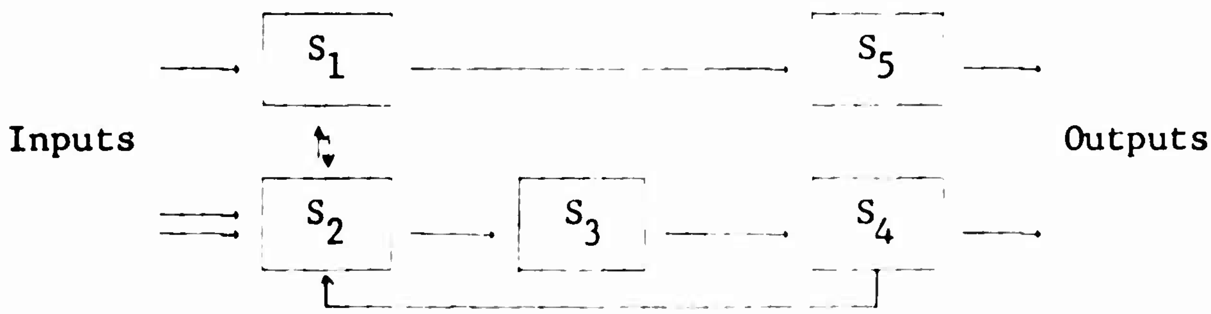
mathematician; unfortunately, it can also act as a very effective loudspeaker for the carnival barker and charlatan. In any case, it is not exactly the kind of instrument that one expects a dowser to carry about with him. Nevertheless, it is closer to a divining rod than any object hitherto created by man. It permits us to carry out numerous feats of prediction, which is to say, precognition, in such domains as astronomy, astrophysics, economics, and medicine, and to examine in detail many objects not only hidden from human eyes, but hidden from all other instruments of observation as well. What allows the mathematical dowser, clutching his digital diviner, to twitch significantly in these mysterious areas?

To answer this question, it is necessary to examine the general nature of scientific research. To the scientist, the system under study, be it of economic, biological, medical, astronomical, or atomic nature in origin, initially assumes the form of a 'black box." By this useful and traditional term, we mean that nothing is known about the inner structure of the system. All that we know is contained in a listing of inputs and outputs.

Inputs → System S → Outputs

To learn about the mechanisms of S. experiments are carried out. New inputs are used to modify the old outputs, and to generate new ones. Outputs not previously noted are now measured. As more results become available, plausible hypotheses can be made concerning the internal structure. One purpose of this is to be able to predict how the system will react to changes in input and environment.

Eventually, the original black box is decomposed into a set of subsystems, with interconnections and feedbacks.



The foregoing procedure is now repeated to ascertain the detailed structure of the subsystems, to determine the nature of the linkages, and so on.

In terms of the foregoing, we can now state one of the consuming problems of science: "Given a system about whose structure something is known, with some information about the inputs and outputs, determine the missing information about the inputs, outputs, and structure." This we may name the "system identification problem."

This is an abstract version of problems studied in nuclear physics, in economics, in biomedicine, in genetics, and in hundreds of other disciplines. Much of the time there is a simple, direct reply: Perform additional observations and experiments. If one is curious about the nature of a system, don't waste too much time on speculation—go out and look at it. This "common sense" point of view took roughly about 90 per cent of the time accorded to what we call "modern society" (i.e., 8000 BC to the present), to gain acceptance. Unfortunately, in many interesting and quite important situations, we cannot accept this advice because we possess no means for observing the system in action.

Thus, for example, we possess no measuring devices which can look deep into the interior of the Sun or any other star; we cannot observe what is going on in the heart or the brain; we cannot see the interior of an electron; we cannot penetrate a depth of ten miles into the earth. In all of these cases, first-hand information is unavailable. We must be content with the results of "probes" of various types, data furnished by cameras, telescopes, radio-isotopes, seismographs, cardiographs, electroencephalographs, Dow-Jones averages, and so on.

The situation is further complicated, almost to an unbearable extent, by the fact that many other systems are emitting signals at the same time. As a result, the desired output is entangled with many other extraneous outputs, and it is very easy for the information we want to be swamped by information we don't want.

Consequently, we are usually on one or the other horns of a dilemma: either we are in the situation where we must fill in the gaps using incomplete information, or we are inundated by data and we face the problem of filtering out the answer from a welter of numbers. Enter, at this point, the mathematician and his digital computer.

Referring to the complicated block diagram in Fig. 2, suppose that our objective is to study the properties of the little black box, S_3. We have carefully drawn the picture, so that all inputs and outputs are indirect. How then do we "observe" it? We begin by noting that S_3 does not exist in isolation. It is linked by way of inputs and outputs to the other subsystems. These linkages may be expressed by means of mathematical equations, frequently quite complicated and often quite numerous. As a matter of fact, these equations are of such perplexity and prolixity that up until only a few years ago people did not even bother writing all of them down. What is the point of cabalistic symbols if they do not cast a spell?

These equations are too difficult to solve explicitly, say the way one solves a quadratic equation, and they are too difficult for numerical manipulation, using a slide rule or even a desk computer. But—with a digital computer at our side, we can approach them confidently.

The tens, hundreds, and even thousands of equations that describe the interactions of the components of a complicated system can now be solved simultaneously in numerical terms. No matter that it is an economic system or an endocrine system, a complex of winds and temperatures, or of electrons and protons. Using the information we possess about available parts of the system, we can deduce the structure and functioning of the inaccessible parts. We can thus measure where it is convenient or cheap to do so, or where it requires easily obtained equipment; we can perform painless and quick diagnostic tests as opposed to many now current for want of better. The digital computer thus acts like a mathematical periscope, enabling us to gaze at will into forbidden areas.

With the aid of these large-scale calculations, we can test assumptions, hypotheses, and thus theories, on a vast scale. Does an astrophysicist have a pet theory about the composition of the atmosphere of Venus; a neurophysiologist about pathways for control of the fingers; a cardiologist about the functioning of the heart; a geologist about oil prospecting? All of these are susceptible to the same direct, straightforward examination by means of mathematical equations and digital computers.

Why engage in all of this? For some, it is sufficient to gain understanding, and then to press on to more severe challenges of man-cum-computer; to others, this alone is not sufficient. For these, there is the reward of constructing an "early-warning" system for

heart disease, or cancer, or brain damage; or inflation, or depression, or automation; or hurricanes or floods or earthquakes. In any case, both kinds of scientists are pressing in the same direction, toward the time when the most sophisticated mathematical concepts and the most advanced technology will combine to work the greatest of all magic, that involved in providing for mankind a surcease to pain and an abundance of the necessities of life.